BASIC RADIO TRANSMITTER DESIGN AND CONSTRUCTION

ARUP KUMAR SEN

A radio transmitter is basically a powerful radio frequency signal generator. However, to have a very high degree of frequency stability, a power oscillator is not used to generate the signal in practice. Instead, a commonly used LC oscillator (Hartley, Colpitts etc) is used to initiate the generation at a very low power level. It is then amplified to get the required output power. Crystal oscillators are used for signal generation when rock-still frequency stability is desired.

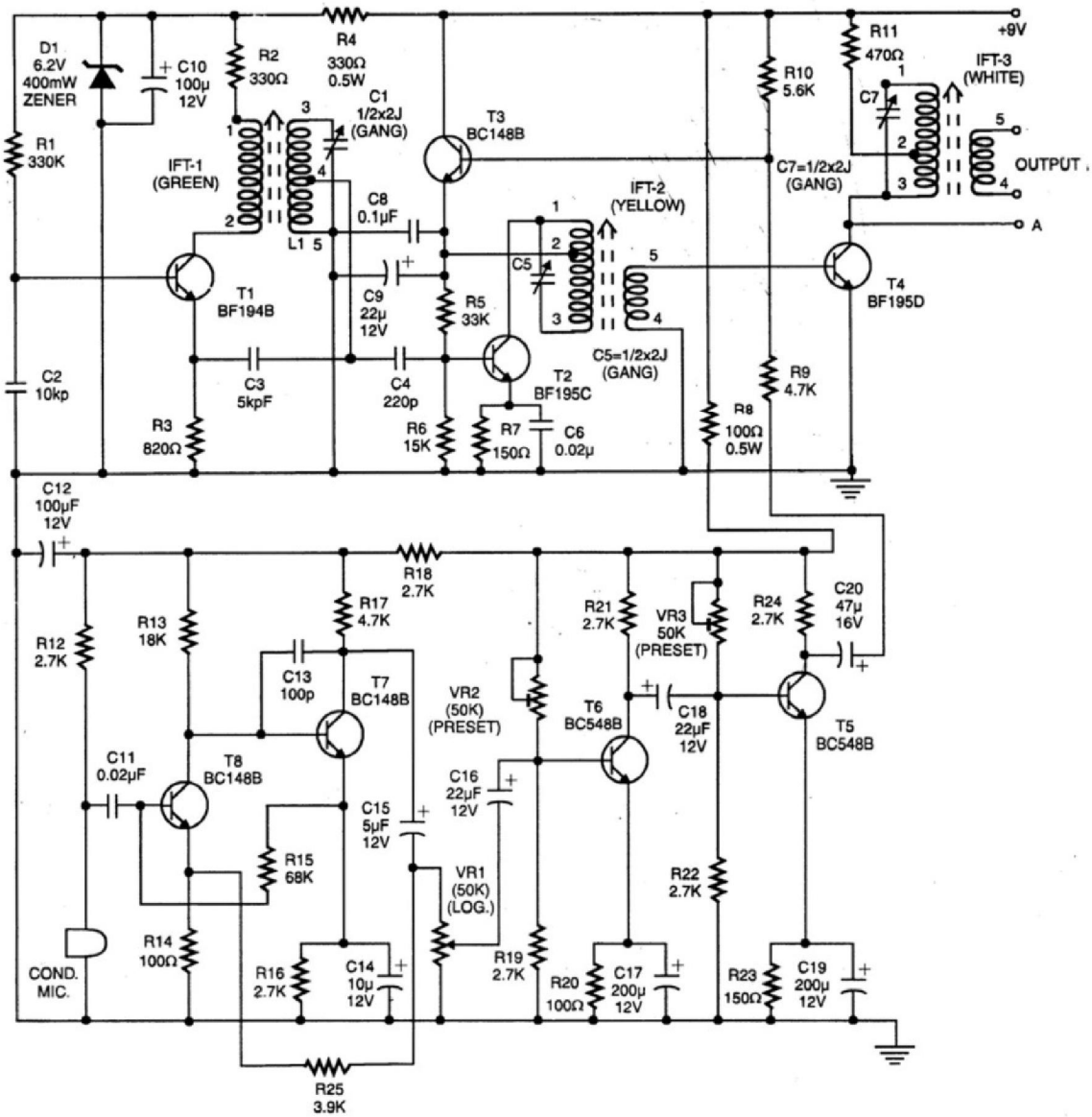

Fig. 1: Circuit diagram for the transmitter.

The aerial or antenna acts as a link between the transmitter and the outside world. It transfers the RF energy produced into the space. The energy then propagates in the form of electromagnetic waves, to distant points, to be communicated with.

The information to be transmitted (speech or sound) is first transduced to electrical signal and then it is superimposed upon the RF signal. The process of super-imposition or modulation changes the parameters of the RF signal (say amplitude) by the amplitude of the transduced signal. RF signal is then called a carrier wave.

The essentials of a basic radio transmitter are shown in practical circuit in Fig. 1. Various considerations made while designing the circuit are discussed below.

Oscillator

Since the frequency is not very high, and since this is only a demonstrative circuit, a Hartley oscillator has been used as the frequency source. Quiescent current flowing through the RF transistor is kept very low to get the minimum harmonic distortion. The values of inductance (L1) and capacitance (C1) are chosen to obtain a frequency of 7 MHz, using the formula

$$f = \frac{1}{2\pi\sqrt{L1C1}}$$

The oscillator is operating in the common base mode. The reactance of capacitor C2 should be very low (0.22 ohm here) at this frequency.

Since stability of the frequency depends, to some extent, upon the stability of the collector or base supply potentials, both are supplied by a zener regulator. As the oscillator consumes very little power, a small zener diode (400mW) can do the job of regulation quite adequately.

Capacitor C4 couples the oscillator signal to the RF amplifier. Its reactance being high compared to that of capacifor C3, feedback signal required for oscillations remains practically the same. Minimum coupling assures a good frequency stability too.

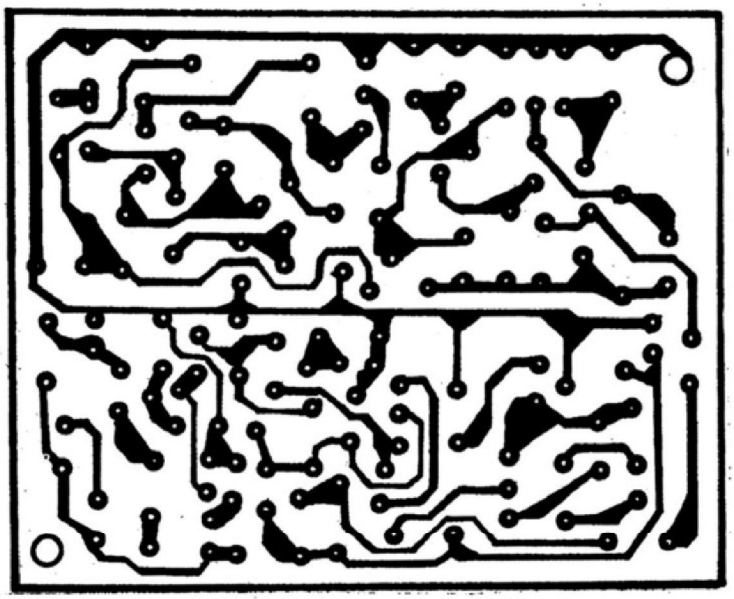

Fig. 2: Actual-size PCB layout for the circuit shown in Fig. 1.

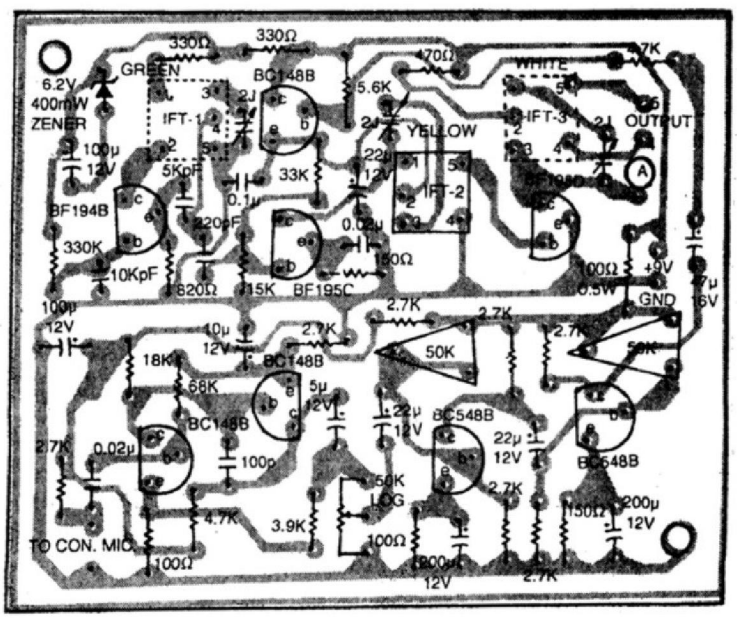

Fig. 3: Component layout for the PCB shown in Fig. 2.

PARTS LIST

Semiconductors:

T1	— BF194B, npn transistor
T2	— BF195C, npn transistor
T3,T7,T8	— BC148B, npn transistor
T4	— BF195D, npn transistor
T5, T6	— BC548B, npn transistor
D1	— 6.2V, 400mW zener diode
D2-D5	— 1N34 germenium diode

Resistors (All 1/4 watt ± 5% carbon unless stated otherwise):

R1	— 330-kilo ohm
R2	— 330-ohm
R3	— 820-ohm
R4	— 330-ohm, 0.5 watt
R5	— 33-kilo ohm
R6	— 15-kilo ohm
R7, R23	— 150-ohm
R8	— 100-ohm, 0.5 watt
R9,R17	— 4.7-kilo ohm
R10	— 5.6-kilo ohm
R11	— 470-ohm
R12,R16,R18,R19,R21	
R22,R24	— 2.7-kilo ohm
R13	— 18-kilo ohm
R14,R20	— 100-ohm
R15	— 68-kilo ohm
R25	— 3.9-kilo ohm

Capacitors:

C1,C5,C7	— l/2x2J, gang x 3
C2	— l0kpF ceramic
C3	— 5kpF ceramic
C4	— 220pF ceramic
C6,C11	— 0.02pF ceramic
C8	— 0.1µF ceramic
C9,C16,C18	— 22µF, 12V electrolytic
C10,C12	— 100µF, 12V electrolytic
C13	— 100pF ceramic
C14	— 10µF, 12V electrolytic
C15	— 5pF, 12V electrolytic
C17,C19	— 200µF, 12V electrolytic
C20	— 47µF, 16V electrolytic

Miscellaneous:

IFT-1	— Green
IFT-2	— Yellow
IFT-3	— White
	— Con. Mic.

TABLE

IFT No.	Colour	Turns	SWG	Core Dia
1	Green	1-2 = 7T 3-4 = 14T 4-5 = 5T	39	10mm
2	Yellow	1-2 = 5T 2-3 = 7T 4-5 = 5T	38	10mm
3	White	1-2 = 8T 2-3 = 4T 4-5 = 2T	38	10mm

RF amplifier

The RF amplifier is a tuned amplifier. A parallel resonant circuit is used at the collector. The effective 'Q' when loaded by the next stage input is chosen to be equal to 50 to effect good harmonic rejection.

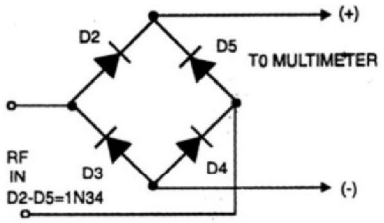

Fig. 4: Circuit for measuring peak value of the signal voltage.

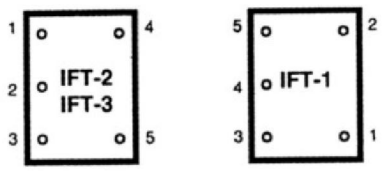

Fig. 5: Pin outline of IFTs

The amplifier operates in class A condition. The output is connected to next stage via mutual inductance coupling. The gain of the stage is only 4.

Power amplifier

The purpose of this stage is to develop an RF power (0.2W) to be fed to a coaxial cable which would carry the signal to the antenna. A high frequency transistor T4 (fr =200 MHz) is used to develop the power. The power rating of this transistor is 300 mW, well above the required power output.

The amplifier is operating under class B condition. This is achieved by grounding the base through the secondary winding of IFT-2. The primary of IFT-3 connected to the collector acts as the LC tuned circuit, in conjunction with capacitor C7. Output is taken from secondary winding. The primary is tapped to get very high sharpness in tuning (high Q value). When loaded, the circuit should show a Q value of 10.

Modulator

As seen from the circuit diagram, the RF amplifier is connected in series with transistor T3. The transistor decides the magnitude of the voltage to be applied to the collector of RF amplifier in accordance with the signal from microphone (after 4 stages of amplification).

Since the output of the RF amplifier depends on its collector potential, transistor T3 does the job of amplitude modulation. Base biasing potential is taken from the same line to enhance the effect.

This type of series modulation may cause total carrier cutoff during negative peak of the modulating signal, if it is too high. However, it gives compactness as it does not require any modulation transformer.

The AF preamplifier is required if microphone is used. But if the signal is taken from line-out terminal of a tape deck, the signal may be applied directly to gain control pot VR1.

Adjustments

To achieve linearity in amplification VR2 and VR3 are to be preset. Connect a scope to the collector of transistor T5 (1 volt/div. and 1ms/div.). Adjust the said presets while speaking through the microphone (keeping gain control in maximum position) to get maximum clear sine wave on screen. It would be approximately 4V P-P, normally. The corresponding DC voltages at the related collectors are found as 7V and 4.5V respectively. During transmission, the gain control alone needs to be adjusted to get a clear sound on a shortwave AM receiver.

Construction

During construction it should be ensured that no undesired feedback is present between any two stages. This would create spurious RF radiation, causing instability and loss of power.

To minimise this problem, all the stages should be isolated by proper electrostatic shielding. These should be housed in small metal boxes. All connections should be made through feed-through capacitors or coaxial cable. IFT1 through IFT3 are wound over 10mm standard IFT drum core. All connecting leads should be as small as possible to reduce unwanted inductive reactance.

If battery eliminator is used to run the transmitter, an RF filter should be inserted in between the eliminator output and the transmitter to minimise radiation through power line. Unwanted modulation by power line hum may be reduced by proper grounding of the negative supply line to transmitter.

Tuning

The transmitter would be of no use if it is not perfectly tuned. All the amplifiers must be adjusted to give maximum amplification on a particular frequency, i.e. frequency of the carrier wave to be radiated into space.

The best instrument for tuning is the oscilloscope. However a voltmeter may also be used to get the job done. If neither is available, a high-impedance multimeter (50k ohm/volt or more) may be used to read the peak value of the signal voltage when connected as shown in Fig. 4.

If an oscilloscope is used for tuning, low capacitance probe should be used to avoid the detuning effect possible when scope is disconnected. Follow the steps given below for tuning:

Step 1. Connect the probe to the base of RF amplifier. Set capacitor C1 to get the desired frequency. The cup core of the IFT should be removed.

If scope is not available a shortwave receiver may be used for the purpose. Rotate the dial of the receiver to tune the oscillator output. Signal may come on more than one position of the dial when it is very close to the oscillator. Position on which maximum output is heard gives the frequency of the desired signal. That can be read from the dial directly.

Step 2. Connect the scope or meter to the collector of the RF amplifier. Rotate capacitor C5 to get the maximum undistorted peak-to-peak signal on scope or maximum deflection on meter before doing step 3. AF signal to the modulator should be cut off.

Step 3. With cup cores of IFTs completely in, measure the signal at collector of transistor T4. Adjust tuning capacitors C5 and C7 to get maximum undistorted signal.

Slight mistuning may produce a complete no signal condition. This would ensure the ability of the tuned circuits to reject unwanted frequencies.

Step 4. Connect a resistance of 50 ohms at the output terminals and retune capacitors C5 and C7 to get maximum voltage across it. This should be nearly 10 volts peak-to-peak.

Step 5. For effective transmission, the antenna should be connected to the output terminals through transmission line (coaxial) after removing the resistance. The antenna should have a length 5 per cent shorter than that of half wavelength of the carrier wave. In this case of HF transmission, it would be an impractical figure to mount. The problem can be overcome if a *n* type network is inserted in between the output and

the antenna.

Step 6. Once tuning is complete an AF signal may be applied to the modulator. Adjust the AF gain control to get a clear and loud signal on a shortwave receiver.

Typical application

The unit can be used effectively for communication between rooms of a large multistoried building. A long piece of wire may then act as an antenna if connected to the terminal marked as A.

If required, the output power may be further increased by using another push-pull amplifier stage after transistor T4.

❑

Readers' Comments:

❑ I want the author to clarify the following points:

1. Is it possible to change the frequency range of transmitter up to 10 metres (26 to 30 MHz) by changing the value of inductor L1 and capacitor C1?

2. What does the author mean by a 'pi' type network? Please explain in detail?

3. What is the range of the transmitter?

Joy Mukherjee
Lucknow

❑ I request the author to clarify whether we can use the commercially available IFTs directly.

Rajesh Chakraborty
Dhanbad

The author Arup Kumar Sen replies:

1. It would be possible to increase the frequency range of the transmitter if proper care is taken for sheilding and neutralisation. Otherwise, self-oscillations may occur. Besides, the performance of the transmitter may get degraded.

2. Matching 'pi' type network is the most frequently used impedance matching network employed for transmitter output stages. It is in reality made up of two 'L' type networks in which the separate sections match the two terminating impedances (source and load).

3. The open air range of the transmitter depends upon the antenna type, receiver sensitvity, and its signal-to-noise ratio etc. Even without giving any special importance to the antenna, I got a clean signal at a distance of about 5 kms in a highly congested locality using a 5-meter ordinary wire antenna.

In reply to Rajesh, I am sorry to inform you that no such IFT can be used directly, as its inductance would be much higher than the required value. However, readymade IFTs can be procured from Kits 'n' Spares, 303, Dohil Chambers, 46, Nehru Place, New Delhi by money order or DD.